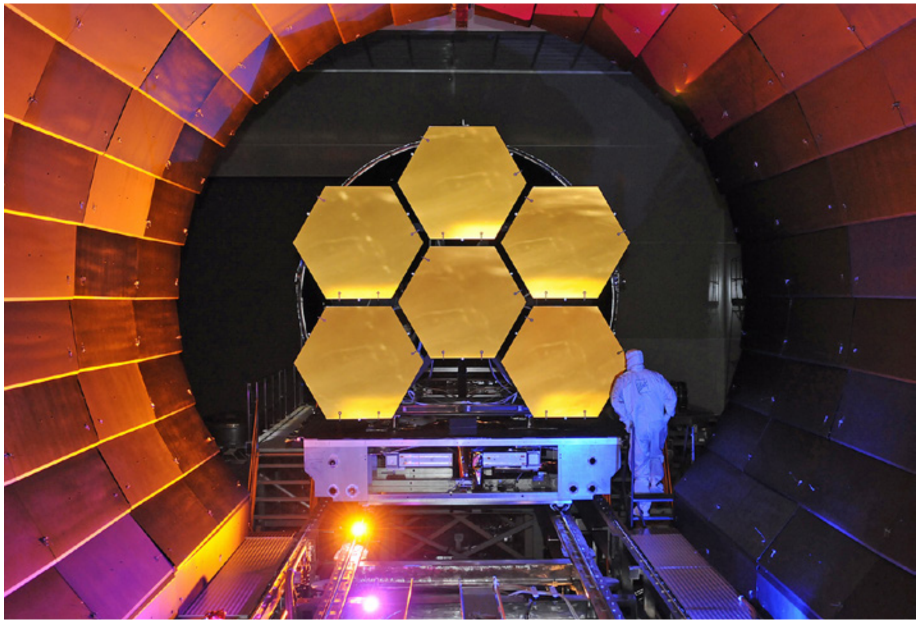
ASTRONOMY BEAT

Giving Birth to the James Webb Space Telescope: Part 2

John Mather (*NASA Goddard Space Flight Center)*

Editor's note: The ASP concludes its inside look at the James Webb Space Telescope (JWST) with the second half of a two-part Astronomy Beat. *In the previous issue (#110), John Mather described the early days of the Webb project, including budget constraints and the challenge of designing an observatory that was completely impossible to build with old technologies. Now that the instruments are mostly complete, John looks at what remains to do prior to (and after) launch.*

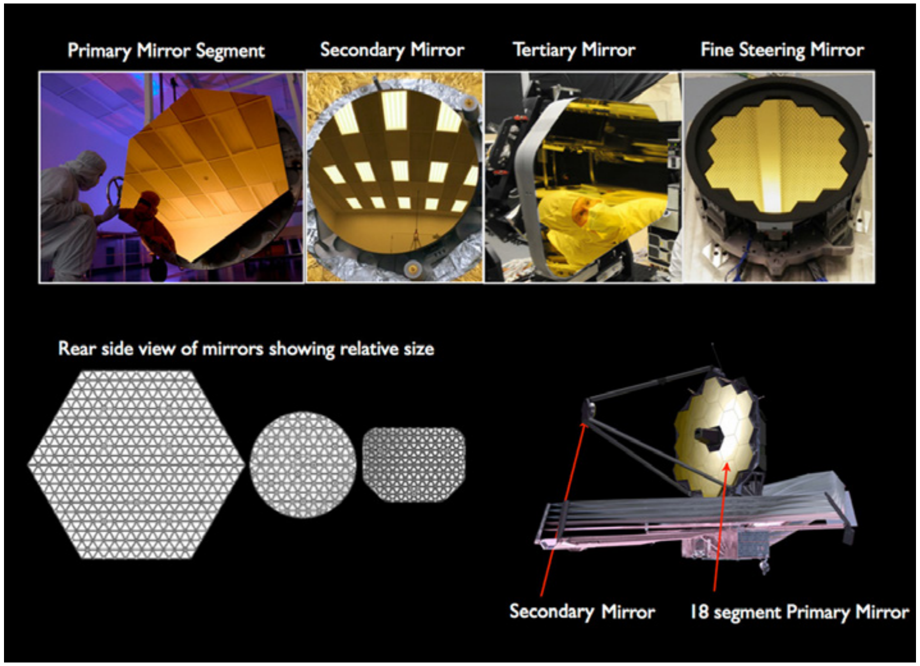


Six of the flight mirrors for the James Webb Space Telescope undergo cryogenic testing at NASA Marshall. Courtesy Ball Aerospace.

Status Report

As of early 2013, the Fine Guidance Sensor (FGS) and Mid-Infrared Instrument (MIRI) have been delivered, and the Tunable Filter Imager (TFI) was reconfigured to become the Near-Infrared Imaging Slitless Spectrometer (NIRISS), which was delivered with the FGS to create the FGS/NIRISS package. The Near-Infrared Spectrograph (NIRSpec) was finished and passed its tests, but then tiny cracks were found in its optical bench (a large, stiff surface for mounting the parts). Fortunately, the European Space Agency (ESA) had a spare optical bench, and almost all the parts have been transferred over. The Near-Infrared Camera (NIRCam) is definitely behind schedule, but we have a plan to accommodate that, and the Integrated Science Instrument Module will be ready in time. We discovered more than a year ago that the near-infrared detectors using mercury cadmium telluride (HgCdTe) technology were degrading. However, the fault has been found and new ones are being manufactured that are at least as sensitive as the old ones.

All of the telescope mirrors have been polished, tested, coated, and mounted on their motorized adjustment fittings, and are being shipped to Goddard Space Flight Center (GFSC). We made a 1/6-scale



Did you know there are four different types of mirrors on the Webb telescope? There's one large mirror consisting of 18 segments, plus a secondary, tertiary, and a fine steering mirror. The bottom right illustration shows an artist's concept of Webb in flight and the location of the primary and secondary mirrors. The bottom left shows the first three mirrors drawn to the same scale and from the rear to illustrate the honeycomb structure that makes these mirrors both very light and mechanically stiff. Courtesy NASA, Ball Aerospace, and Tinsley.

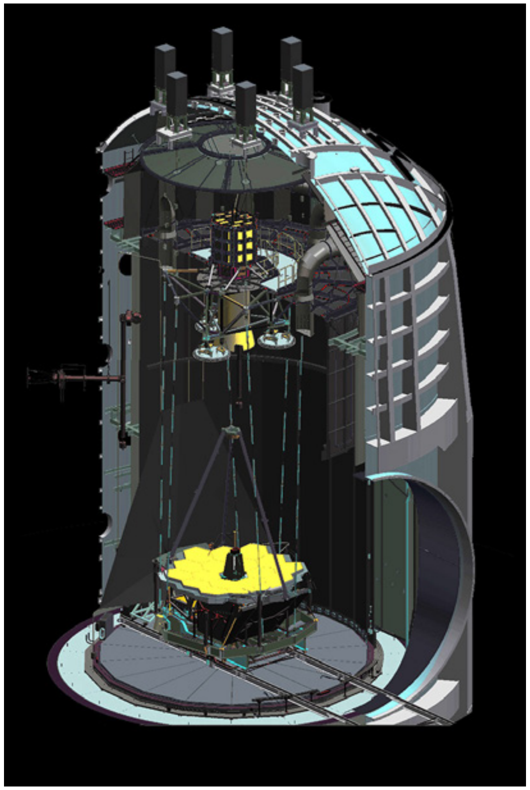
model of the telescope in its post-launch configuration so we could practice focusing it. So the hardest technological developments have already been finished. The spacecraft bus design was deferred for cost reasons, but it is now being completed and key parts are being built. The giant sunshield, as large as a singles tennis court, has been redesigned several times as we learned how to do it, and full-scale test pieces have been produced and measured — they achieve the required shape which includes straight edges to prevent warm parts from shining directly on the telescope.

We have now begun the process of assembling the parts and testing them. Needless to say, the best laid plans 'gang aft agley,' so we've allowed plenty of time (and budget) to find problems, fix them, and then test again. The instruments are already fully tested and calibrated by the time they arrive at GSFC.

Assembly and Testing

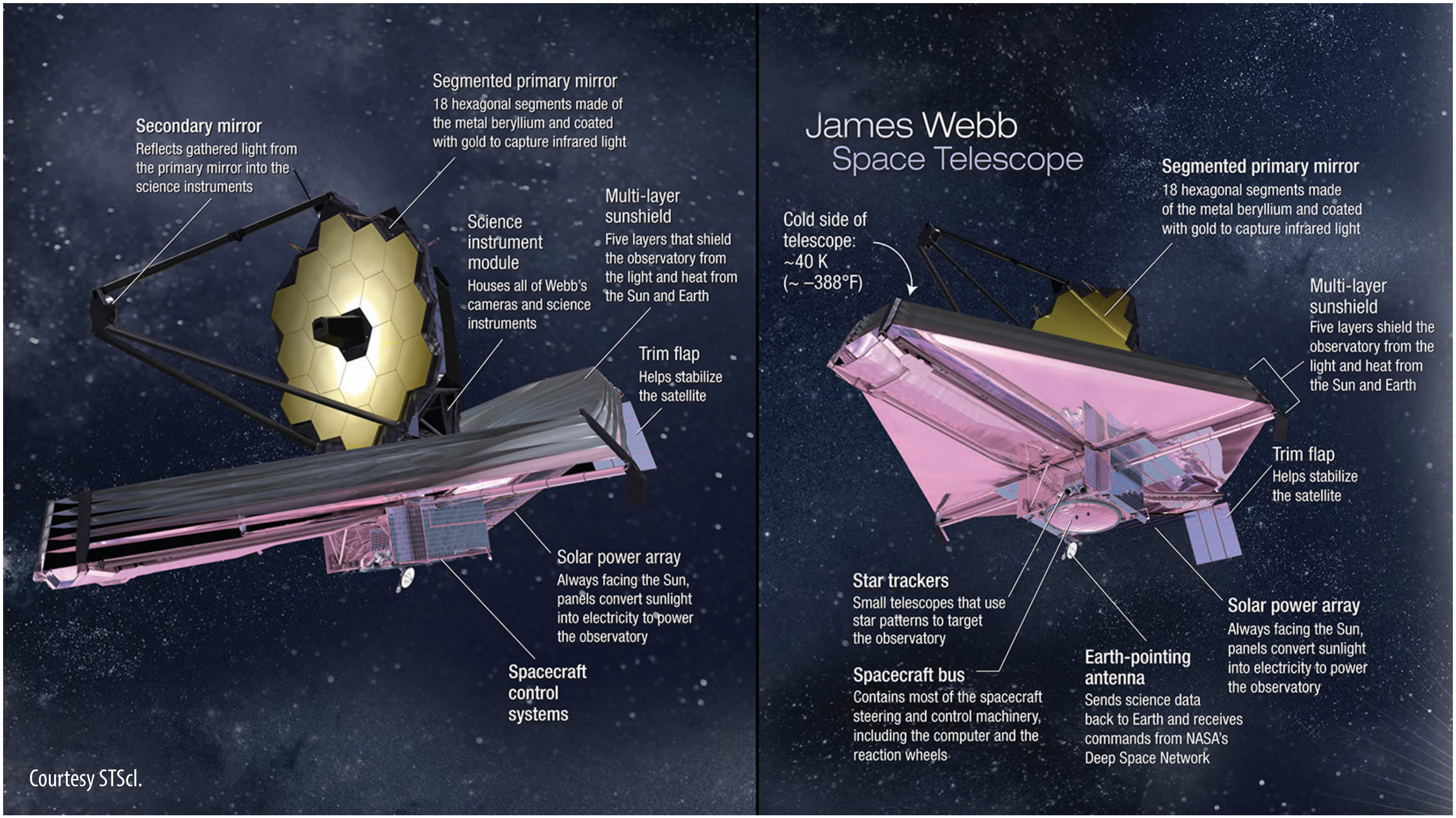
At Goddard we begin by testing the test equipment; the telescope simulator has been cooled down and behaved well. Next, we will assemble the instruments into the support structure and test them with the telescope simulator. This will be done in three stages, to learn as we go, using test versions of the NIRCam and NIRSpec until the flight units arrive. When the instrument module is complete and tested, we will integrate it with the telescope in the great clean room at GSFC, the same one where astronauts (and then robots) rehearsed the Hubble Space Telescope upgrades and repairs.

When the telescope focuses as well as it should at room temperature and in air, we will fold up the whole unit (as it would be for flight), put it in a special truck, drive it to Andrews Air Force Base and into a giant C5A aircraft, and then



This sketch shows Webb inside Chamber A at NASA's Johnson Space Center in Houston, Texas. Test equipment is normally inserted into the chamber via a precision mobile crane, but Webb is so large, it will be folded up and wheeled in. Courtesy NASA/JSC.

fly it to Johnson Space Flight Center near Houston. There the instrument/telescope package will be prepped for its test in Chamber A. That chamber was built for the Apollo astronauts to practice exiting the lunar lander onto the Moon's surface, and it's actually on the National Historic Register as part of the National Park Service! Since then it has been upgraded with a gaseous helium refrigerator, so the telescope can be cooled to its flight operating temperature of about 45 kelvin (-228°C / -379°F). The optical test interferometers have already been built, so that we can confirm the end-to-end focus is working. Then the telescope and instrument package will be folded up again and flown to the Northrop Grumman plant near the Los Angeles airport, where it will be combined with the spacecraft bus and the sunshield, and tested yet again.



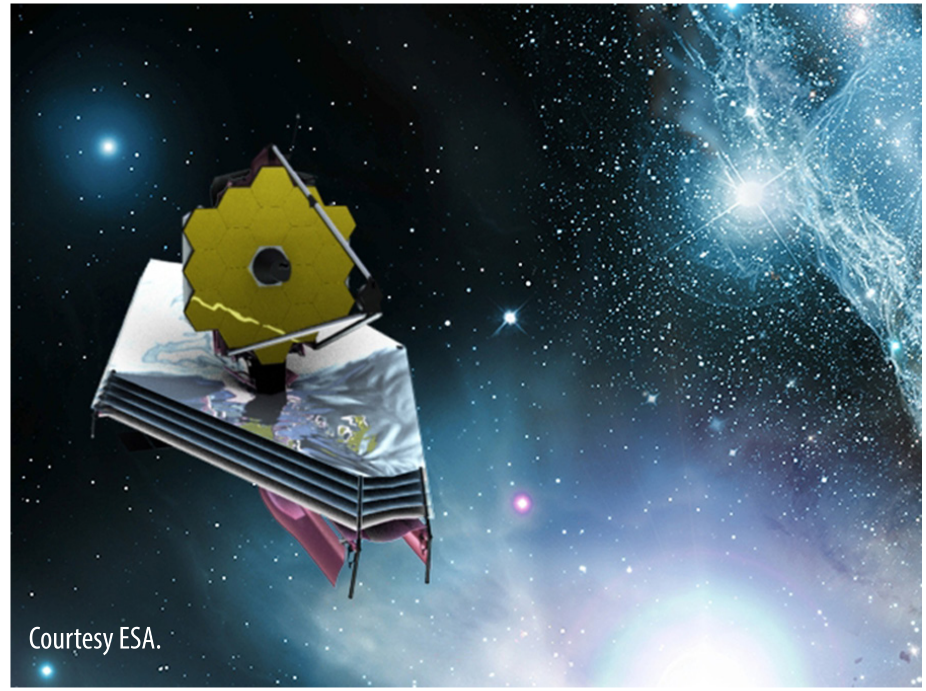
Courtesy STScI.

Launch and Beyond

Cutaway illustration of Webb in its launch configuration at the top of the Ariane 5 launcher and a close-up of its folded state on top of the rocket. Courtesy Arianespace, ESA, NASA.

When that's finished, the full-up observatory will be shipped on a barge through the Panama Canal to the launch site — Kourou in French Guiana. From there, it will be launched on the Ariane 5 direct to its orbit around the Sun-Earth Lagrange point L2. Launch is planned for late 2018, and there are significant funding and schedule reserves to make this very likely.

Within hours of launch, the telemetry antenna and solar cells will be deployed, and during the first few days we will deploy everything else. It will take two months before Webb reaches its final orbit — coincidentally the time it will take for the telescope and instruments to cool down to their operating temperature. After another four months of engineering tests and careful focusing, the telescope will be ready for its first scientific observations.



Courtesy ESA.

We've required the observatory to last for at least five years of scientific observations, and we're carrying fuel enough to last for 10. (We need fuel for orbit adjustments, because the orbit is unstable. Even though Webb is at equilibrium, solar radiation pressure produces torque on the observatory that requires minor maneuvers to offset it.) If we are lucky about the performance of the Ariane, and we learn how to minimize fuel consumption, it's possible the observatory could last much longer. When it's almost out of fuel, we'll send it off into interplanetary space so it can't hit Earth (or even come close for many decades, if ever).

What will we see? That depends on what astronomers propose to look at. As with Hubble, if you want to observe, you assemble a group of colleagues and write a proposal. In it you explain why your chosen targets are interesting, what you will do with the data, how

What Will Astronomers Use the JWST to Study?

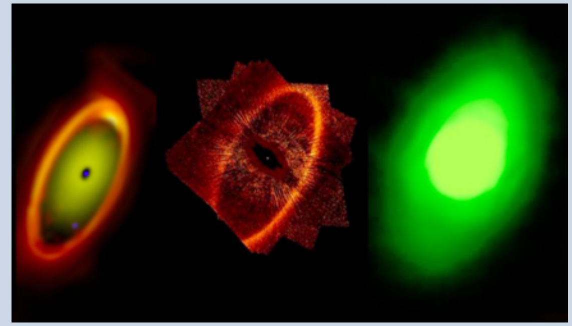
The launch of the James Webb Space Telescope will be a giant step forward in our quest to understand our place in the universe. The Webb telescope will examine every phase of our history: from the first galaxies to form after the Big Bang, to the formation and evolution of planetary systems capable of supporting life, to the history of our own solar system. Webb will be the premier space observatory for astronomers worldwide, extending the tantalizing discoveries of the Hubble Space Telescope, the Spitzer Space Telescope, and giant ground-based telescopes. Here are some of the topics astronomers want to explore using the Webb space telescope.

First Light: After the Big Bang, the first galaxies probably formed as groups of very massive stars. As these stars finished their lives in explosions called supernovae, elements such as carbon, oxygen, and iron were formed and blown into space to seed future generations of stars. The Webb telescope will find and study the first-light objects.

Galaxy Assembly: Large galaxies are assembled through mergers of smaller ones. Webb will observe galaxies at all stages of development with broad wavelength coverage and Hubble-like image quality. The result will be a complete picture of galaxy assembly from the epoch of first light through to the present.

The Birthplaces of Stars: Stars and planetary systems form within nearby dust clouds, which hide the details of this process from view. JWST — observing in infrared light that can penetrate these dusty shrouds — will reveal the environments within these stellar nurseries and the conditions for formation of planetary systems.

Planets and Life: Webb will study the evolution of planetary systems and the ways they could support life. It will explore the distribution of organic molecules and water in our own solar system, identify planetary footprints around other stars, image young planets in nearby systems, and study the atmospheres of planets as they transit parent stars.



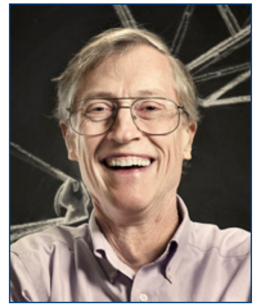
JWST simulated infrared image of the dusty debris disk around Fomalhaut *(left)* compared to the visible light seen by HST *(center)* and the 24-μm image seen by the Spitzer Space Telescope *(right)*. JWST (simulation): G. Rieke, Univ. of Arizona. HST: P. Kalas, Univ. of CA Berkeley. Spitzer: K. Stapelfeldt, JPL-Caltech.

much the work will cost, and why you are the best people for the job. If you are very lucky (around 90% of HST proposals are rejected), your proposal is accepted and your targets are observed. Then you get your data, and you have a little while (up to a year, depending on what privileges you requested) to write up your discoveries and publish them before other scientists can look at the data too.

What would you want to look at? Almost everything! The JWST is so much more powerful than anything else we have had to observe at IR wavelengths, that whatever we could do before, we can now do better and faster — we can see much farther than before, and get sharper images. We anticipate proposals on topics ranging from the first objects to form after the Big Bang to the formation and evolution of galaxies, the formation of stars and planetary systems close to home, the evolution of planetary systems, and the possibility for life to occur elsewhere in the universe.

I'm sure images from Webb will be just as magnificent as Hubble's pictures, and equally sure they will tell us things we don't even suspect yet. After all, every mission we've ever launched has raised questions about the cosmos that we never thought to ask. That will be the most exciting part.

About the Author



John C. Mather is a Senior Astrophysicist in the Observational Cosmology Laboratory at NASA's Goddard Space Flight Center. He is also the JWST Senior Project Scientist. John shared (with George F. Smoot) the 2006 Nobel Prize in Physics for "their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation." This article is dedicated to the 10,000 (or so) future users, and more than 1,000 current team members, of the James Webb Space Telescope.

Resources

- "The James Webb Space Telescope" by Jonathan P. Gardner and Heidi B. Hammel. *Mercury,* Spring 2013: http://astrosociety.org/publications/mercury-magazine. This article is an overview of the JWST project by two scientists who have been intimately involved in the project for many years.
- NASA's website for the JWST: www.jwst.nasa.gov. The Space Telescope Science Institute also has a JWST website: www.stsci.edu/jwst, as does the European Space Agency: http://sci.esa.int/science-e/www/area/index.cfm?fareaid=29.
- Watch Webb's progress on two webcams at Goddard: www.jwst.nasa.gov/webcam.html.
- At NASA's JWST News Archive www.jwst.nasa.gov/news_archive.html you can instantly access all the Webb news releases.
- "Behind the Webb" is an ongoing video series about the telescope: http://webbtelescope.org/webb_telescope/behind_the_webb/archive.
- Here is a webpage with materials for educators: www.jwst.nasa.gov/teachers.html.
- Of course the JWST is on Facebook www.facebook.com/webbtelescope and Twitter https://twitter.com/NASAWebbTelescp, and the telescope even has its own YouTube channel http://www.youtube.com/user/NASAWebbTelescope.
- *James Webb Space Telescope Science Guide*. This free e-book features video, image galleries and more to tell the story of the Webb Telescope (also available as a non-interactive PDF) www.nasa.gov/topics/nasalife/features/e-books.html. ✦

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